Biomimicry as an authentic anchor: Designing interdisciplinary professional development for middle school teachers (DRK12)

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Background
Integrating science and engineering in middle school can enhance students' problem-solving skills, creativity, engagement, and knowledge acquisition (NAE & NRC, 2014). Biomimicry engineering design challenges are effective in integrating science and engineering because they require students to use inspiration from biology to solve human problems (ISO, 2015; Vanderbilt, 2012). Interest in biomimicry in STEM education is growing (Gurjar, 2025), but questions remain about how teachers learn to support students' biomimicry-based design work. Although professional development (PD) commonly addresses science and engineering practices, there are only a few programs focused on biomimicry. As part of the Biomimicry as an Authentic Anchor (BAA) project (Grant No.2300433), which is funded by the DRK12 program of the NSF, we designed and facilitated professional development (PD) for middle school STEM teachers to support them in creating and implementing their own biomimicry-related curriculum. In this paper, we report on findings from the past two years of our iterative approach to developing and implementing teacher professional development workshops.

Method
Using the design-based research (DBR) method, we analyzed iterations of the teachers' professional development(PD) workshops (Design-Based Research Collective [DBRC], 2003). The conjecture map (Sandoval, 2014) shows our hypothesis for how teachers' learning about biomimicry engineering design occurs (Figure 1).

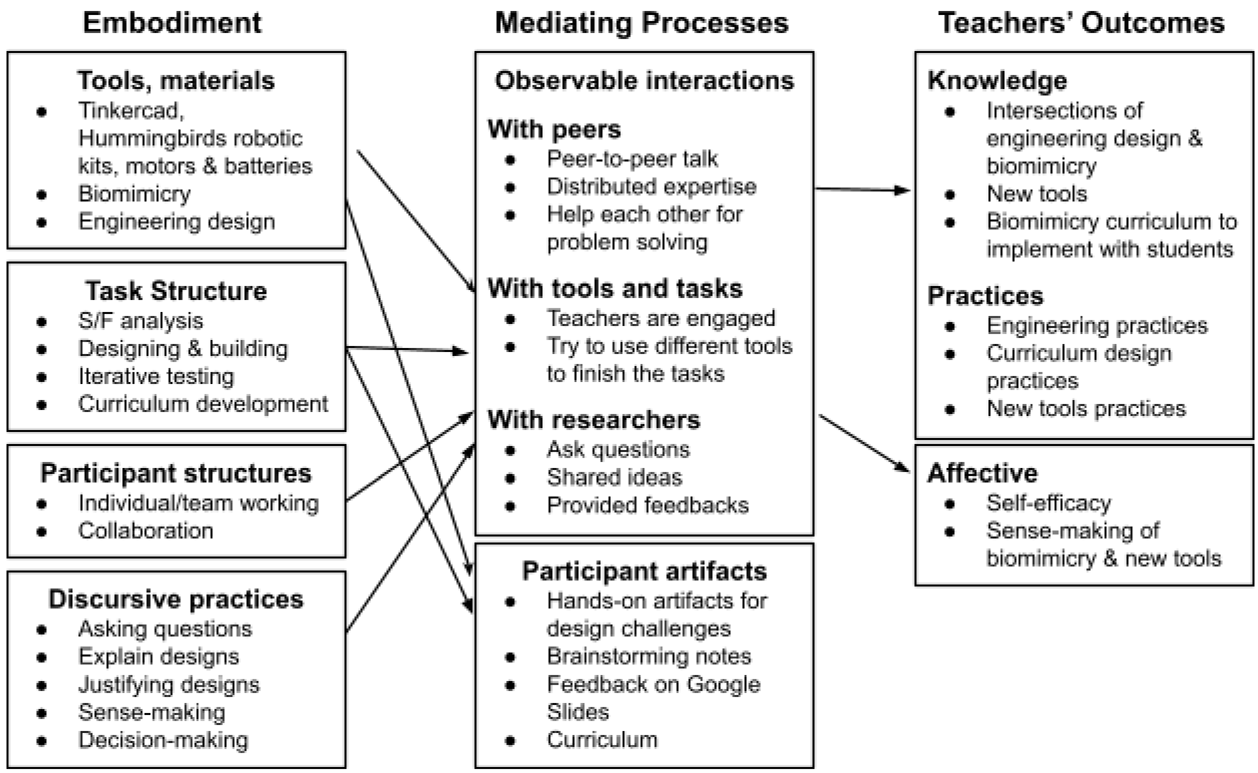

Figure 1. Conjecture map of our biomimicry professional development

Data collection and analysis

Data for this DBR study come from three instances of the PD over the course of two years (Table 1). We collected multiple types of data during each PD, including video and audio recordings, teacher interviews, researcher field notes, pre/post teacher surveys, and PD instructional materials. We analyzed these data to address the question, how and why did the PD design change from year to year, and how did these changes align with the goal of teacher learning of biomimetic engineering design?

PD Version	Number of Participants	Total Number of Days on PD
1 (pilot - Feb 24)	4	3
2 (summer 24)	5	4
3 (summer 25)	8	4

Table 1. Participants and the number of days on each PD

Findings

In each PD, we led warm-up activities and design challenges that focused on 3 different functions: flinging, grasping, and digging. However, we iterated on the technology tools offered for creating design solutions, the scaffolds and resources we provided, and the extent to which we explicitly facilitated teacher collaboration (Table 2). The blue text shows what changed from the last version.

PD Version	**Warm-up activities**	**Flinging challenge**	**Grasping challenge**	**Digging challenge**	**Scaffolds and Resources Provided**	**Extent of Teacher Collaboration**
1 (pilot Feb 24)	Design-a-coaster Flower dissection for s/f analysis	Supply distribution w/ robotics kit	Fruit harvesting w/ Tinkercad	None	"Make a cup" in Tinkercard Helicopter mini-design challenge Padlet Matrix	Mostly working individually
2 (summer 24)	Airborne transport challenge (seed dispersal)	Supply distribution w/ DC motors or robotics kit	Fruit harvesting w/ Tinkercad	Rescue robot w/ DC motors	Structure/Function analysis worksheets Padlet Matrix	Mostly working individually
3 (summer 25)	Airborne transport challenge (seed dispersal)	T-shirt launcher w/ Tinkercad	Fruit harvesting w/ robotics kit	Teacher-choice design goal w/ DC motors	Guided Structure/Function analysis & worksheets More details/supporting materials in Padlet Matrix	Teachers paired to create a digging challenge for another pair

Table 2. Three versions of the PD content

PD Version 1

The first teachers' professional development (PD) workshop was a 3-day pilot, hosted in February 2024 with 4 participants. We conducted 2 warm-up activities: design-a-coaster, and flower dissection for structure/function (s/f) analysis. We chose the first because designing a coaster based on another participant's personal interests would help participants and researchers get to know each other while also engaging in authentic engineering design. We chose the flower dissection activity to introduce participants to the process of analyzing the relationships between an organism's structures and functions, which is a very important practice in biomimicry. After the pilot PD, we realized the design-a-coaster activity created a missed opportunity because it was not biomimicry-related, and the flower dissection activity created a different missed opportunity because it was not engineering-related (the function of flower reproduction was not related to any of the required functions in the engineering design challenges). As a result, we decided to iterate on the warm-up activities in the PD version 2.

For the flinging challenge in PD version 1, we posed a "supply distribution" task with robotics kits. We asked teachers to find inspiration from one or more of three plants or animals that carry out the flinging function, and design a biomimetic solution for supply distribution. For the grasping challenge, we chose to pose a “fruit harvesting” task with Tinkercad, asking teachers to find inspiration from plants or animals that carry out the grasping function, and design a biomimetic solution to gently removefruits from a tree. We chose not to pose a digging challenge in the pilot PD due to the time constraint. We provided two types of scaffolds and resources the pilot PD. First, to help participants learn to use Tinkercad as technology tools for prototyping, we walked them through a “Make a cup” mini-challenge in Tinkercad. And for understanding engineering design, we had a helicopter mini-design challenge. We also provided a Padlet page that included photos, videos, and descriptions of the flinging, digging, and grasping structures and functions of different plants and animals.

PD Version 2

The second PD, hosted in summer 2024, was 4 days with 5 participants. As we reflected after the PD V1, we chose a new warm-up activity that would immediately introduce participants to biomimicry. In this “airborne transport challenge,” participants got inspiration from the structure and function of different seed dispersal mechanisms to design a biomimetic solution for airborne transportation. For the flinging challenge, we still used the same design challenge as PD V1, supply distribution, but in addition to supplying robotics kits for physical prototyping, we also provided DC motors as another technology tool option. This gave an extra option to teachers who prefer to use low-cost tools or wouldn’t have time to teach a new robotics tool. For the grasping challenge, we kept the same design challenge from PD V1 - fruit harvesting with Tinkercad. Instead of the non-biomimetic tutorial, “Make a Cup”, in Tinkercad, for a Tinkercad warm-up, we asked participants to design in Tinkercad the fruit that their design solution would harvest. For the digging challenge in the extra day, we chose to do a “rescue” design challenge using DC motors and batteries as the technology tool. To support participants to better understand structure and function (s/f) relationships and to practice s/f analysis more, we provided s/f worksheets as scaffolds and resources. In the Padlet site of plant and animal inspirations for the design challenges, we added seed dispersal organisms to support the warm-up design challenge and s/f analysis. In PD V2, as in V1, participants mostly worked individually on the challenges, though we facilitated whole-group share-outs at the end of each, and asked teachers to share lesson plan ideas with each other on the last day. After the PD, several participants suggested we provide more s/f analysis practice and supporting materials for lesson plan development, so we planned to iterate on these elements for the next PD.

PD Version 3

The third PD, hosted in the summer of 2025, was 4 days with 8 participants. PD V2’s participants reflected that they liked the airborne transport challenge as the warm-up design challenge, because the structures and functions of seed dispersal are clear and easy to understand. This biomimetic engineering design challenge helped them understand what s/f analysis is, and inspired them to practice s/f analysis with their students. So we kept airborne transport as our warm-up design challenge. For the flinging function, we revised the previous supply distribution challenge into a T-shirt launcher design challenge with Tinkercad. For the grasping function, we kept the fruit harvesting design challenge, but iterated the technology tool from Tinkercad to the robotics kits. And for the digging function, we left more space for participant agency and ownership. Participants worked with a partner to devise their own digging design goal and context. Then, each pair posed their digging design challenge to another pair. Each pair designed a biomimetic digging solution with DC motors. One reason we iterated on some design challenges and switched the technology tools for different design challenges is that three of the participants in PD V3 were returning participants from PD V2. We hoped to provide them with different perspectives on how to use different tools in different design challenges, or how to design the different biomimetic design challenges under each function. Also, we felt that giving participants more agency in the last design challenge would help them develop their own biomimicry curriculum in the future. Based on the participants' reflections from PD V2, we added more guided s/f analysis materials, s/f worksheets, and more details/supporting materials in the Padlet pages, including both organism materials and engineering design supporting materials. In PD V3, participants worked individually for the warm-up design challenge and worked in groups for most other design challenges. We iterated the extent of teacher collaboration because 1) participants in PD V3 were more hesitant to join the whole-group conversations in the first day of the PD, and with a larger number of participants it was easier to separate them into groups where they could feel more comfortable engaging; 2) there were several science teachers and several engineering teachers in this PD, we felt work in groups would help teachers help each other in understanding both biomimetic concepts and how to use new technology tools.

Implications

In general, in these three PDs in two years, we iterated on the length of PD, the timeline, the design challenges, the supporting materials, and the extent of teacher collaboration. The main reason we made these iterations is to provide participants with better support to understand biomimetic concepts and to design their own biomimicry design challenges using different technological tools. We made these iteration decisions from both our research teams' observations and participants' feedback after the PD.

Based on our experience, to design an efficient PD, the research team should ensure the content is aligned with the PD learning goals. Pilot PD is useful. When iterating the PD, consider what is missed, what content is non-necessary and how to improve it to make the PD more efficient, and also get reflections from participants. The PD structure and content should be thought about by the participants, and the research team should make decisions based on the participants' background and PD experiences.

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